91602
new 82-10

ontario hydro
research division

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if
Reproduced in Whole or in Part

To: Mr. D.A. Lee
Manager
Safety Services Department
Health & Safety Division H2 A20

MAGNETIC FIELD RODENT REPRODUCTIVE STUDY (MFRRS) EXPOSURE SYSTEM

S. M. Harvey

An animal containment and exposure system has been designed and built for a Magnetic Field Rodent Reproductive Study (MFRRS). The system consists of four exposure chambers, each with a capacity of 48 mice, and is presently set up in the Animal Sciences laboratory at the University of Toronto. The exposure chambers are designed to generate VLF time-varying magnetic fields similar to those produced by video display units, with time derivatives up to 50 T/s, and to have good space and energy efficiency. 60-Hz magnetic fields up to 1 mT can also be generated. Technical details and performance specifications for the system are provided in this report.

1.0 INTRODUCTION

Starting in 1982, Ontario Hydro planned and carried out a detailed interdivisional study of the possible health hazards of Video Display Units. This study, known as HAVDU (Hazard Assessment of Video Display Units), identified the need for some ergonomic improvements, but failed to find any support for concerns that radiative emissions or electric and magnetic fields produced by the units were causing adverse pregnancy outcomes/1/.

To further address these concerns, a second study known as MFRRS (Magnetic Field Rodent Reproductive Study) has been initiated. The purpose of MFRRS is to expose pregnant mice to magnetic fields similar to those produced by the horizontal deflection coils in VDUs. About 800 mice and field levels up to 3000 times greater than actual human exposures (9000 000 times greater in energy units),will be used in an attempt to find a statistically significant effect on fetal development in the selected mouse strain.

job	file	date	report no.
16-224	817.22	May 27, 1988	88-125-K

89-02601/

B

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, express or implied with respect to the use of any information, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

The Research Division was asked to design and supply an exposure system for MFRRS that would be suitable for installation in a standard animal-care laboratory. The system has now been installed in the Animal Sciences laboratory at the University of Toronto, and is described in this report.

2.0 GENERAL SPECIFICATIONS

The general specifications for the exposure system were developed by a MFRRS technical committee, and may be summarized as follows:

- Four separate, but identical exposure chambers, each with a capacity of 48 mice, are required. All four chambers should be located in a single room in a standard animal-care laboratory.

- The magnetic field in the chambers must have a triangular waveshape with a rise-time to fall-time ratio of 9:1 and a frequency between 17 and 20 kHz. The four chambers must operate with peak-to-peak field amplitudes of 0 (sham exposure), 3.6 μT, 16.8 μT, and 200 μT, respectively, with a uniformity of ±10% over the space occupied by the animals. The maximum time derivative of the field is to be between 30 and 50 T/s.

- The design must allow future operation of the chambers with: (a) a similar triangular waveshape at 60 kHz and a peak-to-peak amplitude of 67 μT, and (b) a sinusoidal 60 Hz waveform having a rms (root-mean-square) amplitude of up to 1 mT.

- The system should have a minimal influence on the normal laboratory environment and animal-care practices, and should comply with approved guidelines for the care and use of laboratory animals.

Preliminary design exercises/2,3/ showed that these specifications could not be met with standard laboratory products and conventional magnetic-field generating apparatus. The system was, therefore, assembled from custom-fabricated components designed to fit together as a self-contained unit.

3.0 OVERVIEW OF THE SYSTEM

The exposure system, shown in Figure 1, is presently set up in a 5.3 m x 5.8 m area in a room in the Animal Sciences laboratory at the University of Toronto. It consists of four exposure chambers placed 3 m apart in a square arrangement. Pending completion of a composite four-chamber driver unit, two prototype "flyback-type" current generators are supplied and may be used to energise any two selected chambers. The current generators are located in one corner, and are connected to a standard 15-A electrical outlet through a twenty-four hour timer that may be used to switch the fields off for three or four hours each day.

Each exposure chamber is made up from two parts. The first part, shown in Figure 2(a), is a free-standing magnetic field generating coil assembled from four "figure-of-eight" windings that are designed to reduce stray fields around the chamber. These windings have two working spaces with equal but oppositely directed fields. The coil is supported on a polyurethane-varnished hardwood table with elevating screws at each corner for fine position adjustments.

The second part, shown in Figure 2(b), is a separate free-standing shelf unit, also made from varnished hardwood, holding eight animal cages on two PVC plastic shelves. When properly positioned, the cages on the two levels fit precisely into the two working spaces of the field generating coil. However, there is no physical contact between the coil and the cage structures. The individual cages hold six animals each, and are made in pairs from clear polycarbonate plastic (figure 3).

Detailed specifications for the coil assembly and animal cages, together with some electric and magnetic field measurements made in the actual test room, are provided in the following sections.

4.0 DETAILED SPECIFICATIONS - COIL ASSEMBLY

4.1 Mechanical

The mechanical design of the coil assembly is determined in part by the specifications for maximum field strength (1 mT) and field uniformity (±10% over the animal cages). However, the design must also be consistent with other requirements such as low power consumption (preferably powered from a standard 120-V, 15-A receptacle), negligible temperature rise at maximum field, minimal electric field, absence of sound and vibration, very low fringing fields allowing close spacing of adjacent chambers, good visual access, and unobstructed access for cage removal.

The coil assembly supplied is an adaptation of the widely used multiple-winding square coil/4,5/. In the present adaptation, the square windings are replaced by windings in which the bottom half is rotated by 180° relative to the top half, producing a "figure-of-eight" configuration. Four windings are arranged along a common axis. The outer windings have two turns each, and the inner windings have one turn each.

The windings are made from "Dekoron" PVC-insulated 1/4-inch copper tubing/6/ and are mounted on robust frames made from polycarbonate plastic (Lexan). Each frame is lined with adhesive copper foil that may be connected to provide an electrostatic shield. Coil dimensions and correct cage positions were selected on the basis of computed fields and are shown in Figure 4.

All four windings are connected in series by means of 1/4-inch tube unions, and unions are also supplied at the coil terminals. Electrical current and water cooling (if required) can, therefore, be supplied through common connections and equal flow of both current and water is assured through all segments of the coil.

4.2 Electrical

Electrical specifications are supplied from direct measurement where practical. However, magnetic fields are calculated from the known physical dimensions of the coil, this method being intrinsically capable of greater accuracy than direct measurement. The results are listed in Table I.

Magnetic field calculations were done on a desktop computer with an in-house program using published coil formulae/7/, but the same results can be obtained with commercial software packages such as MAG-PC/8/. For computational purposes, the total cage volume in each of the two working spaces is taken to be exactly 50 x 50 x 15 cm.

The electrical parameters have been selected primarily to optimize performance in the 20 to 60 kHz frequency range. In this range, the coil impedance will be inductive and the voltage across the coil windings for a constant rate of change of field will be proportional to the number of turns. The lowest number of turns is therefore desirable, not only to reduce the likelihood of generating parasitic oscillations, but also to keep the applied voltage as low as possible. Designs more suitable for other operating criteria may be obtained by following procedures outlined in Appendix I.

4.3 Coil Drivers

The prototype coil drivers supplied at the time of writing are "flyback-type" triangular waveform generators similar to the type commonly used to drive the horizontal deflection coils in VDUs. Two drivers, essentially identical except for current rating, and connected in parallel to a common timing-pulse generator, are supplied. The drivers are set to operate at 20 kHz but are easily reset for 60 kHz operation by changing the flyback capacitor and increasing the timing-pulse frequency. At 20 kHz, one generates magnetic fields up to 200 μT peak-to-peak and the other generates magnetic fields up to 20 μT peak-to-peak.

A schematic of the high-field driver is shown in Figure 5 and a photograph of the 200 μT magnetic field waveform, measured with a specially constructed field probe/9/, is shown in Figure 6.

In operation, the pulse generator is left on at all times and the fields are turned on and off by means of the timer connected between the power supplies and the 115-V receptacle. Because the two higher field intensities (in A^2/m^2) are technically in excess of occupational exposure guidelines/10/ by factors of about 7 and 1000 respectively, a override switch is also provided so that the fields can be turned off manually, if it is necessary to enter the room at unscheduled times.

An improved "linear-type" coil driver unit capable of energising three exposure chambers at the three specified fields, with constant rates of change of field on the rising and falling portions of the triangular waveform, is being developed. The sham exposure chamber will also be connected to this unit to ensure that the experiment is performed "blind". The improved unit will have provision for monitoring the status of the exposure fields and also for automatic entry-control interlocking of the exposure system.

4.4 Fringing fields

The fringing fields produced by the "figure-of-eight" windings decrease with distance according to an inverse fourth power law (similar to a magnetic quadrupole) instead of the inverse third power law of conventional coils. This allows the exposure chambers to be located closer together and essentially eliminates the potential nuisance value of stray radio-frequency fields. Calculated fringing field contours are shown in Figure 7. These show that with four exposure chambers located at the corners of a 3 m square, the field from one chamber will be reduced by four orders of magnitude at two of the remaining three locations.

TABLE I

Electrical Parameters of Coil

General	
Number of windings	4
Total number of turns	6
Winding turns ratio	2:1:1:2
Copper conductor cross-section	0.134 cm^2
Coil inductance	65 μH
Coil DC resistance	.046 Ω
Coil factor (1)	8.50 μT/A
Field uniformity (2)	±8.2%
High-frequency	
Applied voltage for 40 T/s	306 V
Power required at 200 μT	<30 W
Power-frequency	
Applied voltage at 1 mT	6.2 V(rms)
Power required at 1 mT (3)	640 W

Notes:

1. Coil factor is the ratio of the median field over the cage volume to the applied current.

2. Field uniformity is the maximum deviation from the median value over the cage volume. The design permits small variations in cage position without exceeding the specified 10%.

3. Power requirements increase as the square of the field strength. Water cooling will be required for fields greater than about 0.4 mT if 100 W is taken to be the limit for air cooling.

4.5 Electric Field and Noise Generation

Due to the pulsed voltage applied to the coil, a pulsed electric field will exist in the exposure chamber. Electrostatic shielding is provided in the coils to reduce this field.

The effectiveness of the electrostatic shielding was tested by placing a model EFS-3 electric field strength meter/11/ at the center of three different cage locations (two top and one bottom), and recording the field along each of three orthogonal axes. Because the EFS meters give correct field strengths only for sinusoidal waveforms, a 30 V(rms), 20 kHz sinusoidal voltage was applied to the coil for this test. The results are shown in Table II.

TABLE II
Electric field strength in V/m(rms)

Shielding	Cage	E_x	E_y	E_z
Unconnected	1	4.0	2.5	28
	2	4.0	2.5	29
	3	2.4	1.2	17
frames connected but not grounded	1	3.0	1.3	6.0
	2	6.5	1.0	6.5
	3	2.1	<1	6.0
Frames connected and grounded	1	1.2	<1	1.0
	2	<1	<1	2.1
	3	1.2	1.3	1.5

Table II shows that the electrostatic shielding, if grounded, reduces the electric field at the cage positions by a factor of about 15. Scaling by voltage, the pulsed electric field produced in the exposure chambers with the linear coil-driver will be up to 330 V/m peak-to-peak without coil shielding, and will be up to 24 V/m peak-to-peak (approximately 5 V/m rms) with the shielding connected and grounded.

The direct transmission of vibration from the coils to the animal cages is prevented by the absence of any physical contact between the two assemblies, but a sound field (at the coil driving frequency and its harmonics) may exist around the cages. Attempts were made to measure both sound and vibration but the sensors were found to be responding partly to the magnetic field and it was concluded that more refined techniques would be needed to accurately characterize these influences. An investigation carried out by the Mechanical Research Department in an anechoic chamber (appendix 2) placed an estimated value of 25 dB on sound levels .

5.0 DETAILED SPECIFICATIONS - CAGE ASSEMBLY

The animal cages are constructed in two-cage units from 1/4-inch clear polycarbonate sheet (Lexan), and have removable covers cut from commercial grade 3/8-inch eggcrate polystyrene (fluorescent lighting panels). Handles are provided at each end and each cage has a 3-inch by 5-inch cardholder for maintaining records. Cage dimensions are shown in Figure 8.

Individual cages are designed to hold six animals. They have a minimum floor area of 100 cm^2 for each mouse, and a rearing height of 15 cm in compliance with the recommendations of the Canadian Council on Animal Care and the US National Research Council Committee on the Care and Use of Laboratory Animals/12,13/. A water bottle and feeder basket are supplied with each cage and are mounted on the cage cover.

The eggcrate covers are rather brittle and may break if not treated with respect, but are preferable to metal grills in which currents may be induced. They provide an economical solution to the problem of providing cage ventilation, having just about the maximum achievable percentage of open area (about 90%). Because of concerns about using glass or plastic parts for

food supply, a nonmagnetic stainless steel sipper tube and feeder basket are used. However, these parts have no metallic loops and are arranged to keep the area of any low-impedance loops to which they may contribute as low as possible. These precautions should minimize secondary effects such as vibration or enhancement of induced currents, but acceptable levels have not been established.

The cages can be handled and cleaned in the standard manner, but may not fit on standard storage racks. In use, two cage units are positioned side by side on each shelf of the hardwood support structure. Each shelf therefore holds 24 animals in a total enclosed volume of nominal dimensions 50 x 50 x 15 cm. The cages slide easily on and off the shelves, and the shelves themselves are shaped so that the cages are correctly positioned to within 1 or 2 mm when pushed to the back of the shelf. A dummy shelf is provided above the other two in order to equalize illumination levels at the different cage locations.

6.0 ON-SITE MEASUREMENTS

6.1 Fringing Fields

The four exposure chambers are arranged in the basement room so that the calculated magnetic field from any chamber will be down by two orders of magnitude at any wall or ceiling, and down by four orders of magnitude at two of the other three chambers. Measurements made with one exposure chamber operating at 200 μT showed that fringing fields at the other chambers were approximately 0.2 μT, 0.02 μT, and 0.02 μT peak-to-peak respectively, these signals being close to the noise level of the broadband measuring system. The measurements confirm, at least qualitatively, the calculated fringing fields shown in Figure 8. The latter two readings are below the 60-Hz ambient field (see section 6.3), and are considered to be low enough to serve as sham exposures.

6.2 Geomagnetic Field

The earth's geomagnetic field was measured at each of the four chamber locations with a Bell model 640 gaussmeter. As shown in Figure 9, the magnitude and direction of the geomagnetic field are relatively constant. The strength of the earth's magnetic field in the exposure room is nominally 45 μT and the direction is at right angles to the exposure field, within 10°, at all cage locations.

6.3 Electromagnetic Background

Electromagnetic fields present in the exposure room due to background sources were measured prior to setting up the exposure chambers. Power-frequency electric and magnetic fields were measured by Health and Safety Division using a 110 series electric field meter from the Electric Field Measurement Co and a model 42A milligaussmeter from Monitor Industries, respectively. Fields in the radiofrequency bands from 10 kHz to 300 MHz were measured at the center of the room with commercial electromagnetic-field scanning antennas and receivers made by Rohde and Schwarz of Germany, supplemented by handheld broadband probes. The findings are summarized in this section.

60-Hz: The results are shown in Table III. They demonstrate that there are no unusual sources of power-frequency fields in the vicinity of the test room.

TABLE III

60-Hz Electric and Magnetic Fields in Test Room

Location	Electric	Magnetic
NW Corner	0.0025 kV/m	0.105 μT
SW Corner	0.0026	0.088
NE Corner	0.0018	0.030
SE Corner	0.0018	0.030
Center of Room	0.0030	0.015

VLF and LF Frequency Bands: Broadband impulsive-type electric and magnetic fields were observed in these bands. The electric field had an amplitude of about 4 V/m and a spectral density of about 8 V/m/MHz extending up to about 100 kHz. The magnetic field had an amplitude of about 2.10^{-4} μT and a spectral density peaking at about 10^{-2} μT/MHz at 20 kHz. These field levels are fairly representative of a laboratory environment. They were produced, respectively, by the fluorescent lighting and a video display unit located in one corner of the room. No VLF or LF radio broadcast signals were observable in the presence of these sources.

AM Broadcast Band: Broadband impulsive-type fields extend at reduced strength into the AM radio broadcast band. Narrowband signals from AM radio transmitters are observable but have a very low maximum field strength of about 100 μV/m and are effectively masked by the broadband fields. This agrees with independent observations that AM radios do not work very well at this location.

HF, VHF, and UHF Frequency Bands: Electromagnetic fields in these bands are produced largely by television and FM radio transmitters. Signal strengths similar to those produced by AM radio stations, up to about 100 μV/m, were observed.

6.4 Sound Fields

Sound fields were measured in the test room by Mechanical Research Department. This room was found to be quite reverberant due to the hard tiled walls. With one chamber operating at a frequency of 20 kHz and an exposure field of 200 μT, the sound level in the cages of adjacent chambers was measured to be about 20 to 23 dB. The sound level in the cages of the operating chamber was estimated to be about 35 dB. This level is significantly above background in the 20 to 40 kHz frequency range.

7.0 SUMMARY

A magnetic-field exposure system consisting of four exposure chambers, each with a capacity of 48 mice, has been designed according to requirements laid down by the MFRRS Technical Committee. This system has been set up in a room in the Animal Science Laboratory of the University of Toronto. Design details and performance specifications for the exposure chambers are provided in this report and show that the system is generally in compliance with the requirements. The results of some site surveys for background electromagnetic fields are also

included. Work is continuing on an improved composite coil-driver unit and further work may be required to more accurately quantify and if necessary reduce the sound level in the chambers.

Approved:

A.F. Baljet
Manager
Electrical Research Department

Submitted:

S.M. Harvey
Engineer/Physicist
Science Section

REFERENCES

1. Hazard Assessment of Video Display Units, Final Report. Two Volumes. Available from Safety Services Division.

2. Design Criteria for a Small Animal Magnetic-Field Exposure Facility. Research Report No 86-220-K.

3. Magnetic-Field Exposure Apparatus for Small-Animal Studies: Phase II. Research Report No 87-118-K.

4. Design Data for a Triple Square Coil System. R. Grisenti and A. Zecca. Rev. Sci. Instrum. 52(7), July, 1981. pp1097-1099.

5. Uniform Magnetic Field Produced by Three, Four, and Five Square Coils. R. Merritt, C. Purcell, and G. Stroink. Rev. Sci. Instrum. 54(7), July 1983. pp879-882.

6. Available from Shawflex Inc., Rexdale, Ontario, Canada.

7. Electric Parameters in 60-Hz Biological Exposure Systems and their Measurement: A Primer. M. Misakian. NBS Technical Note #1191. 1984.

8. Available from Infolytical Corp., Montreal, Quebec, Canada.

9. An Improved Magnetic Field Probe for Use with the MFRRS Exposure System. Research Report No 88-37-K.

10. TLVs Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment. Annual Publication of the American Conference of Governmental Industrial Hygienists (ACGIH).

11. Manufactured by Instruments for Industry, Inc., Farmingdale, N.Y., U.S.A.

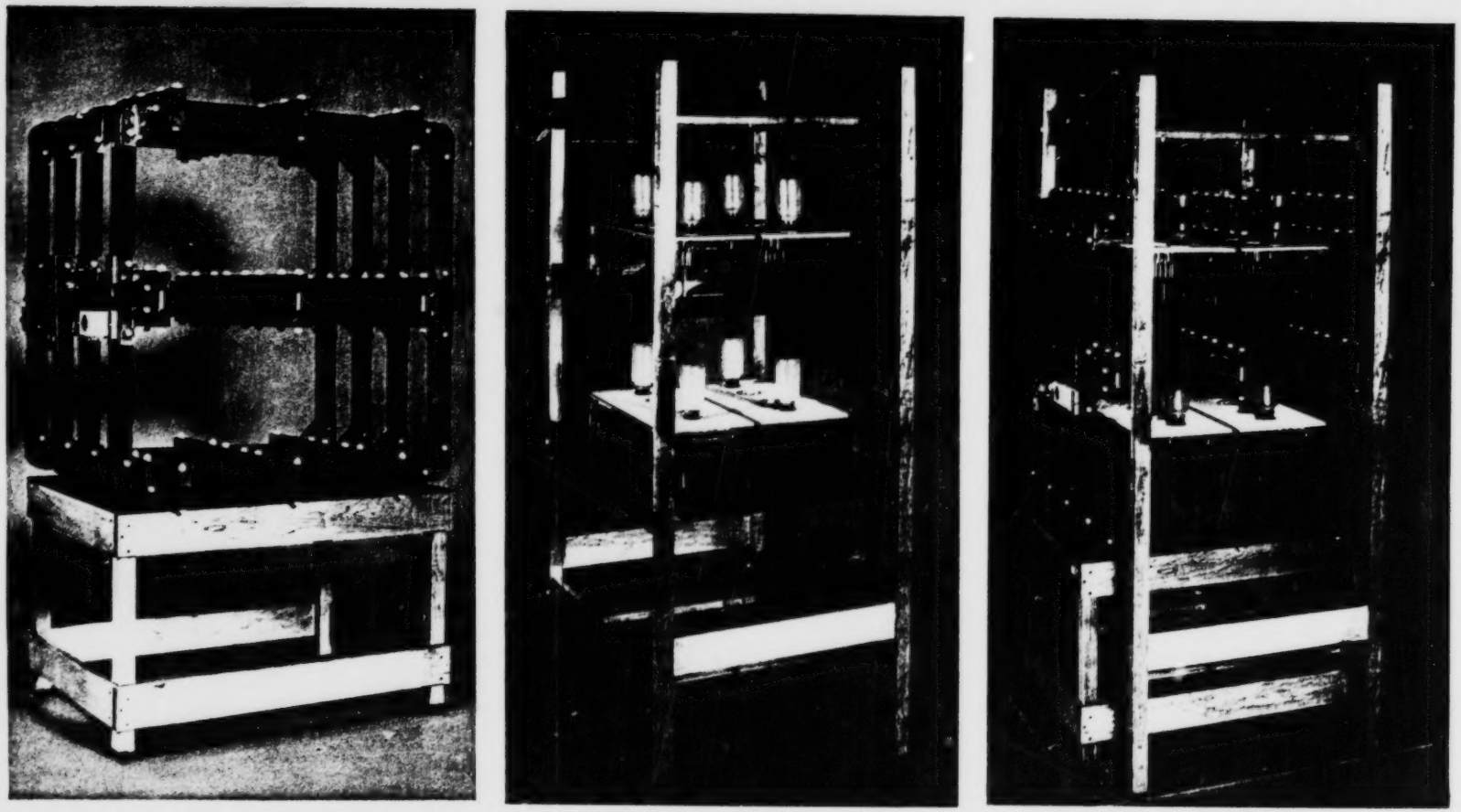
12. Guide to Care and Use of Experimental Animals, Vol. 1. Canadian Council on Animal Care. 1984.

13. Guide for the Care and Use of Laboratory Animals. U.S. Department of Health and Human Services, Public Health Service. NIH Publication No 85-23. 1985.

FIGURE 1

VIEW OF COMPLETE EXPOSURE SYSTEM

177089 RD
GG5



(a) (b) (c)

FIGURE 2

(a) COIL ASSEMBLY
(b) CAGE ASSEMBLY
(c) FULLY ASSEMBLED EXPOSURE CHAMBER

177061 RD
GG5

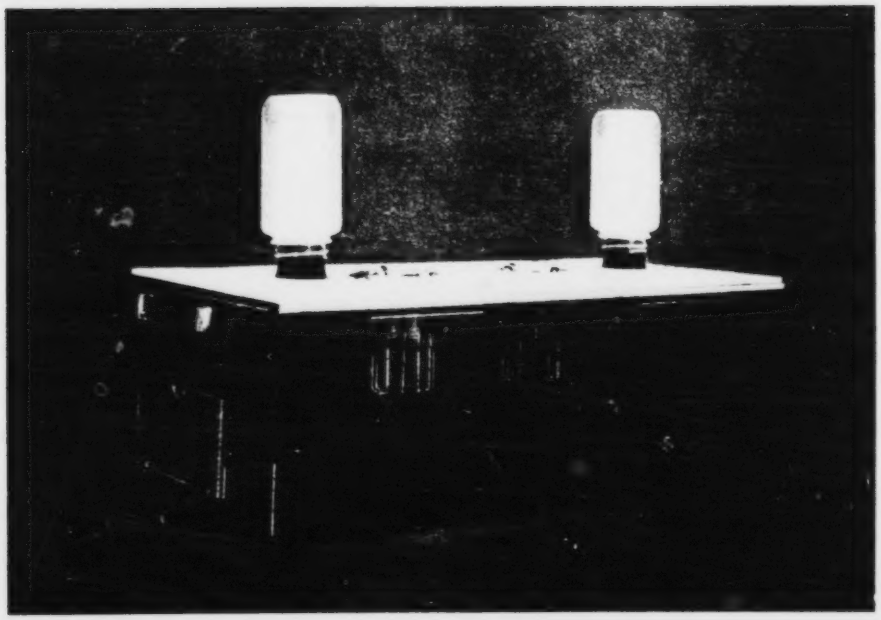


FIGURE 3

2-CAGE UNIT

177062 RD
GG5

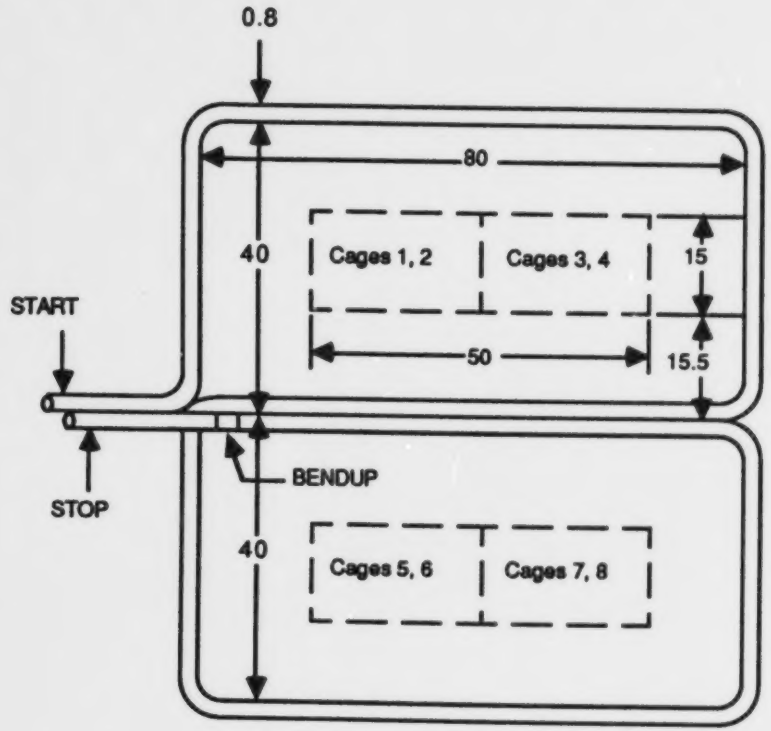


FIGURE 4A

COIL WINDING DIMENSIONS IN cm.
A SINGLE-TURN WINDING IS SHOWN.

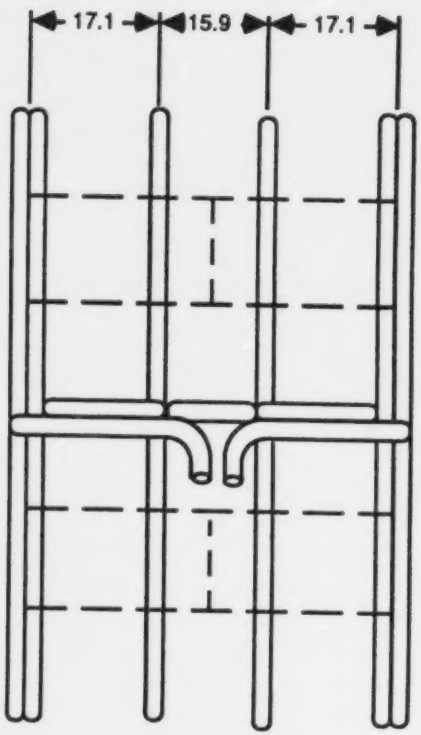
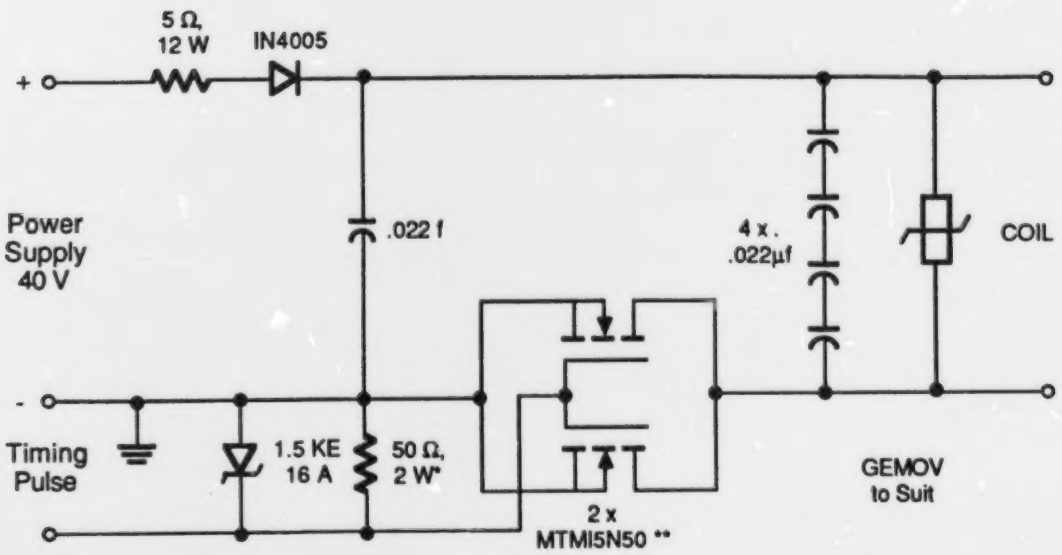


FIGURE 4B

COIL WINDING SEPARATION IN cm.
THE OUTER WINDINGS HAVE 2 TURNS,
THE INNER WINDINGS HAVE 1 TURN.

88-125
177063-RD
GG 5



* Deleted on Low-Field Unit
** 2 x M TP2N45 Used IN Low-Field Unit

FIGURE 5

SCHEMATIC OF HIGH-FIELD COIL DRIVER

FIGURE 6

WAVEFORM OF 20kHz, 200μT PEAK-TO-PEAK MAGNETIC
FIELD MEASURED IN EXPOSURE CHAMBER (TOP TRACE).
THE BOTTOM TRACE SHOWS THE WAVEFORM OF THE APPLIED CURRENT.

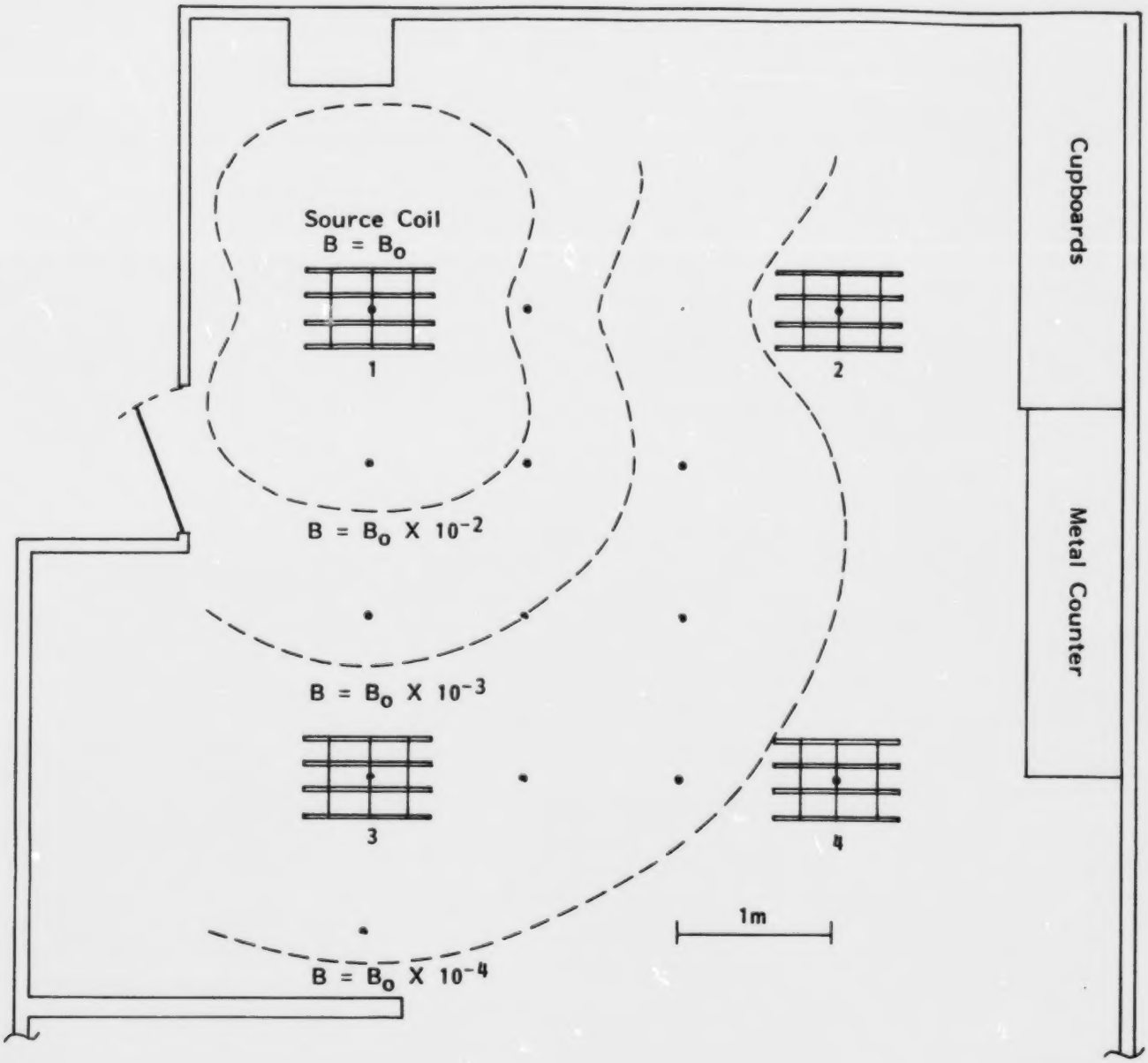


FIGURE 7

CALCULATED FRINGING - FIELD CONTOURS SUPERIMPOSED ON A PLAN VIEW OF THE EXPOSURE ROOM

177066 RD
GG5

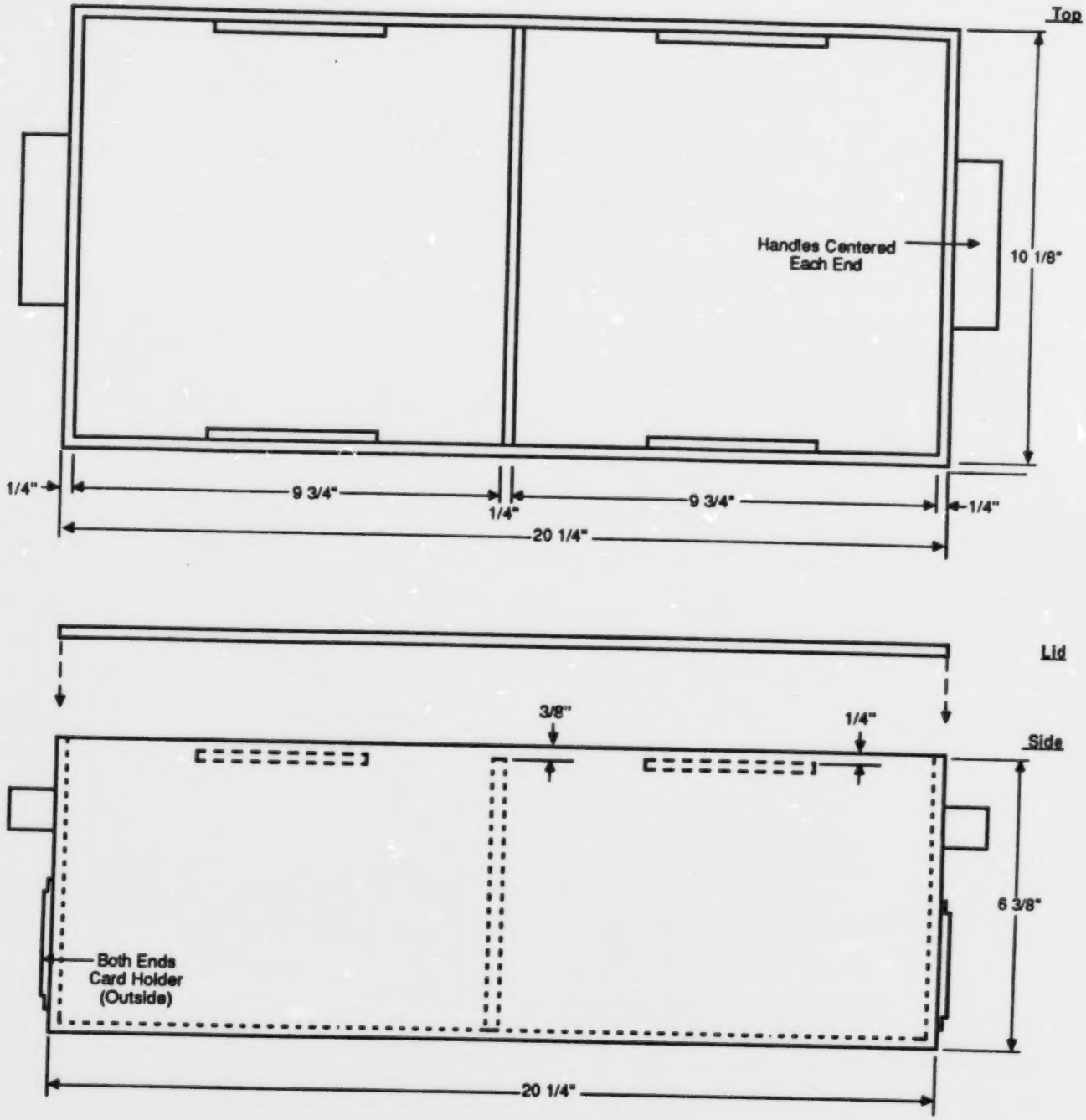


FIGURE 8

CAGE - UNIT DIMENSIONS
MATERIAL - 1/4-INCH POLYCARBONATE

177087 RD
003

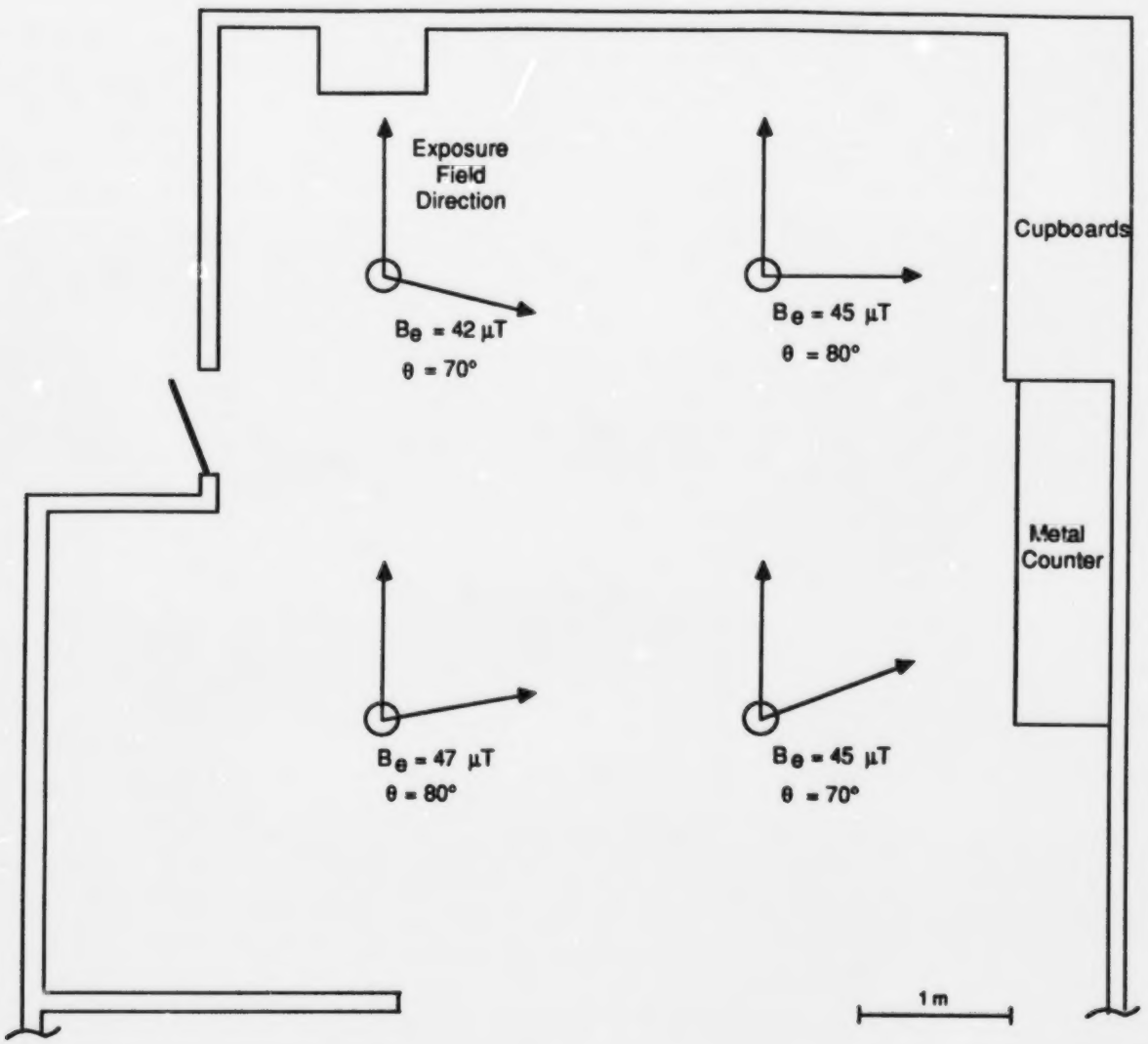


FIGURE 9

MAGNITUDE (B_e) AND DIRECTION OF GEOMAGNETIC FIELD IN THE EXPOSURE ROOM. THE ARROWS SHOW THE HORIZONTAL COMPONENT DIRECTION AND θ IS THE DIP ANGLE (RELATIVE TO THE HORIZONTAL).

APPENDIX I

Procedure for Modifying Coil Design to Meet Different Electrical Source Criteria.

The basic parameters required to describe a field generating coil are: (a) the dimensions, turns ratio, and connections (series or parallel) of the windings; (b) the total number of turns; and (c) the cross-sectional area of the copper conductors. Generally, the dimensions and turns ratio are completely determined by the field configuration required, ie the distribution of the generated field over a given volume, and good engineering practices such as conserving space and energy. Parallel connections are not considered here because they may lead to uneven current distributions.

Modifications to adapt a coil to different electrical sources are therefore limited to the total number of turns and the conductor cross-section. Let these be represented by N and A respectively.

For a fixed field strength, the change in the resistance (R), inductance (L), applied voltage (V), applied current (I) and power dissipation (P) produced by a change in N or A are given to a good approximation by the following formulas. The "primed" quantities apply to the modified coil.

$$R'/R = N'A/NA'$$

$$L'/L = (N'/N)^2$$

$$V'/V = \left\{ \frac{(A'/A)^2+(wL/R)^2(N'/N)^2}{1+(wL/R)^2} \right\}^{\frac{1}{2}}$$

$$I'/I = N/N'$$

$$P'/P = NA/N'A'$$

It is clear that any two of the above electrical parameters can be selected as required but that the remainder are then determined by the choice of N and A.

As an example, suppose that the coil described in this report is required to operate at 60 Hz and a field strength of 2 mT (rms). Tests show that the electrical requirements are as follows:

V = 12.3 V
I = 236 A
P = 2560 W

These parameters impose certain cost and operating constraints. Specifically,

- a non-standard (in many locations) 30-A electrical outlet is required.
- a 10:1 step-down transformer is required. This transformer and any ancillary equipment such as voltage regulators, etc. must have a minimum rating of 3 kVA.
- harmonic filters with a nominal current rating of 250 A may be required with the transformer.
- bus conductors having a minimum size of AWG-3/0, or the equivalent in water-cooled tube, are required. Stray fields from the conductors will be large and not easily controlled by twisting the conductors.
- The coil itself must be water cooled.

To remove these constraints, an operating voltage of 115 V and a power dissipation of 100 W may be specified. The modified coil then has the following characteristics:

$N' = 120$ (40:20:20:40)

$A' = 0.171\ cm^2$

$R' = 0.721\ \Omega$

$L' = 0.026$ H

$V' = 115$ V

$I' = 11.8$ A

$P' = 100$ W

The modified coil can therefore be supplied directly from a standard 15-A outlet and connected with conventional AWG-14 twisted-pair conductors. Stray fields from the conductors will be insignificant. The power factor is 0.07 and if this is corrected with a shunt capacitor, the required current may be further reduced to about 1 A. It is assumed that with a power dissipation of 100 W or less, no water cooling is required. On the down side, the modified coil will contain about 90 kg (200 lb) of copper.

APPENDIX 2

ontario hydro
research division

Dr. F.Y. Chu
Section Head (Acting)
Science Section
Electrical Research Department

PRELIMINARY ASSESSMENT OF ULTRASONIC NOISE IN AN ELECTROMAGNETIC TEST RIG FOR SMALL ANIMALS

J.J. Kowalewski

1.0 SUMMARY

Initial attempts to detect and quantify ultrasonic sound inside a magnetic field generating coil proved to be difficult. No conclusive evidence of sound was obtained due to inevitable strong magnetic influences on the acoustic instrumentation. However, an estimate of "maximum" sound level expected in the rig test area was derived from measurements made in anechoic room conditions. This was in the order of 25 dB (re 20 μPa) at the coil driving frequency of 20250 Hz and its first harmonic.

Recommendations for alternative means of verifying this information and other considerations are given.

2.0 INTRODUCTION

2.1 At the request of Dr. S.M. Harvey, Science Section of the Electrical Research Department, a preliminary assessment was made of the ultrasonic noise produced by an experimental test rig comprised of a magnetic-field generating coil. This rig was constructed by the Science Section for conducting studies of magnetic effects on small animals.

2.2 The magnetic field generated was 200 μT, (p-p) with a nominal driving frequency of 20 kHz. Sound in this frequency range is not audible to humans (unlike to some animals); consequently this assessment was totally dependent on acoustic instrumentation.

2.3 A major difficulty with this task, of course, was separating any ultrasonic noise signal from the magnetic field signal, both picked up by the acoustic instrumentation.

2.4 Dimensions of the test rig were approximately 80 x 55 x 80 cm (L x W x H).

3.0 PROCEDURE

3.1 All acoustic measurement attempts were made with the test rig operating inside a 30 m^3 anechoic chamber in the Applied Acoustics Laboratory, Mechanical Research

Department. Earlier it was found that some of the associated electronic equipment of the rig was producing sound in the ultrasonic range. Consequently, the associated electronic equipment was isolated outside the anechoic chamber.

3.2 The acoustic instrumentation used in this study was capable of measuring airborne sound with high precision over the frequency range 0.001-50 kHz. These were:

- Microphone B&K 4133, S/N 1359144
- Preamplifier B&K ZC 0020
- Cable B&K A0 0027
- Sound Level Meter B&K 2231, Module BZ 7100
- Ultrasound filter B&K 1627 (set of "ultra")
- Dummy Microphone adapter B&K JJ 2614
- FFT Signal Analyzer NSC 446
- Calibrator GR 1986 (set for 74 dB re 20 μPa at 4 kHz)

3.3 The general approach was to minimize the influence of the magnetic field on the instrumentation while looking for any residual increase in the total signal due to sound. These are some of the methods that were tried:

3.3.1 Signal comparison using the real microphone vs a "dummy" microphone (ie equivalent capacitor).

3.3.2 Remote scanning through a plastic tube microphone adapter. Length 1.8 m, ID 19 mm.

3.3.3 Remote scanning through a glass tube microphone adapter. Length 2.0 m, ID 8 mm.

3.3.4 Magnetic shielding using section of iron pipe over parts of microphone, preamplifier and cable connection.

3.3.5 Acoustic shielding of microphone and of rig using a plastic cap and plywood board, 6 mm thickness, respectively.

3.4 Limitations of each of the above methods were verified acoustically by controlled tests using a high frequency sound source (tweeter) and sinewave signal generator.

4.0 RESULTS AND CONCLUSIONS

4.1 Scans made at various distances around the rig using the real and the dummy microphones gave similar results. For example, at 1 m from the rig there was a tonal signal of 15 dB amplitude coincidental with the magnetic coil driving frequency 20250 Hz and its first harmonic 40500 Hz. Therefore, the magnetic signal was found to be masking any possible sound signal at those frequencies.

4.2 Scans made inside and outside the rig using the two types of microphone tube adapters did not reveal conclusive evidence of sound. The tubes, however, exhibited a significant loss in sound transmission at the frequencies in question thus limiting measurements of low level sounds (ie 10 dB for the 19 mm tube and 25 dB for the 8 mm tube).

4.3 Magnetic shielding with the iron pipe did not change the signals detected; consequently this method was inconclusive.

4.4 Acoustic shielding of microphone and/or of the rig did not change the signals observed. This strongly suggests that if sound was being emitted by the rig, it must be at an amplitude below the signals that were observed.

4.5 Based on the most "reliable" measurement taken of 15 dB at 1 m from the rig, the estimated maximum sound level inside the rig test area is 25 dB.

4.6 Electronic equipment associated with the test rig and other such devices commonly found in laboratories emit significant levels of sound at various ultrasonic frequencies.

5.0 RECOMMENDATIONS

Based on these preliminary findings, the following recommendations are presented:

5.1 An alternative method to determine whether or not sound from the magnetic coil is either audible or a concern to the small animals tested, could be to use their biological reaction as an indicator.

With the test rig inside an anechoic chamber, expose briefly a sample of live small animals to a controlled sound source and then to the magnetic field. The sound could be adjusted to be similar in characteristic to the magnetic field and could be used to determine the threshold of audibility of the small animals at the subject frequencies. Compare the biological reaction of the small animals to both stimulus to deduce if sound would be a factor in the study.

5.2 Ultrasounds emitting from auxiliary equipment associated with the test rig or from other laboratory equipment or activities may be audible to small test animals and should be isolated from the test area.

5.3 Reduce any existing sound transmission from the test rig by wrapping acoustical insulation on its magnetic coil and frame assembly.

5.4 Investigate means for shielding acoustical measuring instrumentation from ultrasonic frequency magnetic fields.

We hope these findings and recommendations are helpful and we would be pleased to provide further assistance if required.

Approved:

T. Loewen
Supervising Engineer
Plant Equipment Dynamics Section
Mechanical Research Department

Submitted by:

J.J. Kowalewski
Research Engineer - Applied Acoustics
Plant Equipment Dynamics Section
Mechanical Research Department

JK:is